Kepler's "Sweet Spot"

A White Paper Submitted in response to NASA's call for Alternate Science Investigations for the Kepler Spacecraft

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Abstract

Although the Kepler spacecraft has only two operational reaction wheels there should be, in principal, a spacecraft orientation in which the attitude disturbance torque due to solar radiation pressure is minimized, and the remaining reaction wheels have sufficient control authority to provide high pointing accuracy for 10 to 30 days at a time. This white paper describes this optimum orientation (or "Sweet Spot") relative to the sun, an observing strategy and potential targets to be investigated during alternate science investigations by the Kepler Spacecraft.

Optimum Orientation

Since Kepler is in a heliocentric, drift-away orbit, the only significant disturbance torque for the attitude control system is due to the misalignment between the center of mass (CM) of the spacecraft and the center of pressure (CP) due to solar radiation impinging on the spacecraft. Figures 1 shows the location of the CM and CP for Kepler that I calculated based on the information I was able to find in open sources and on the Internet[1].

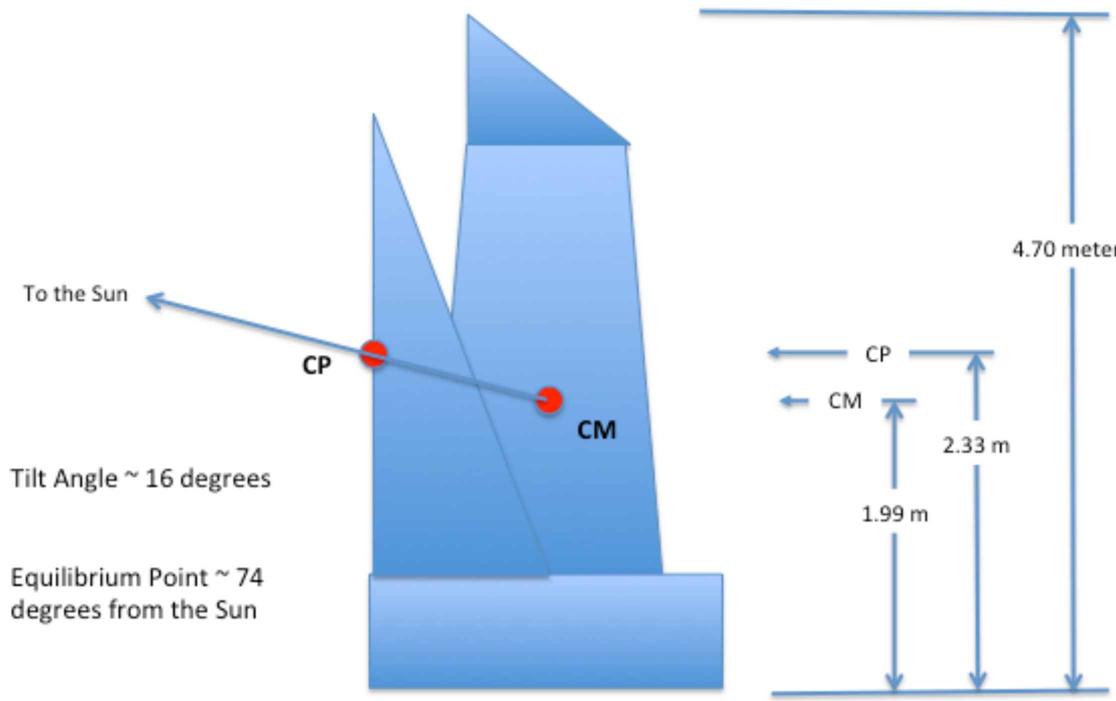

Figure 1. The center of pressure for Kepler will be aligned with the center of mass when the spacecraft is tilted ~15.7 degrees from the sun, and the telescope field of view is center on a spot ~74.3 degrees from the sun, minimizing the solar radiation pressure disturbance torque

[1] "As-built" mass properties and a detailed computer model of the spacecraft are required for a more precise calculation.

These calculations show the CM and CP will be aligned (located on the line from the CM to the Sun) if the spacecraft is tilted ~15.7 degrees toward the Sun. Thus the disturbance torque for the attitude control system will be minimized when the angle between the Sun-line and the telescope line-of-sight is equal to ~74.3 degrees. This spacecraft attitude should minimize the control authority required by the reaction wheels and maximize the accuracy with which the spacecraft can be pointed[1]. Note, in this attitude the solar array provides ~96% of its peak power output.

There should also be an "island of stability" around this "Sweet Spot" (Table 1), perhaps 4 or 5 degrees in radius, in which the spacecraft pointing is only slightly less accurate. Thus is should be possible to hold Kepler on a target 74 degrees from the sun from 10 to 30 days, depending on its ecliptic latitude. Table 2 shows the length of time Kepler could remain on target as a function of ecliptic latitude assuming only ± 5 degrees of solar motion.

Kepler "Sweet Spot"		
Angle from Sun	74.29	degrees
Power Loss	3.73%	
Ecliptic Latitude	74.29	degrees
Daily Motion	0.2668	degrees
Allowable Offset (±)	5.0	degrees
Days of Stability	37.48	days

Table 1. The optimum pointing for Kepler to minimize solar disturbance torque

Ecliptic Lattitude	Daily Motion	Days of Stability
74.29	0.2668	37.5
0	0.9856	10.1
10	0.9707	10.3
20	0.9262	10.8
30	0.8536	11.7
40	0.7550	13.2
50	0.6336	15.8
60	0.4928	20.3
70	0.3371	29.7
80	0.1712	58.4
55	0.5653	17.7

Table 2. Days of stability for Kepler at maximum pointing accuracy as a function of Ecliptic Latitude

Observing Strategy

In a year's time, all objects at ecliptic latitude < 80 degrees will be in Kepler's "Sweet Spot" for 10 to 30 days at a time, including the stars in Kepler's original star field in the Cygnus-Lyra region (Figure 2).

Objects at ecliptic latitudes < 65 degrees should be observable twice each year: first when the target is at ecliptic longitudes greater than the ecliptic longitude of the Sun (with the telescope field of view leading the sun), and a second time when the target is at ecliptic longitudes less than the ecliptic longitude of the Sun (with the telescope field of view trailing the sun).

There are several observing modes that could be adopted for Kepler's alternate science investigations: e.g., a survey mode that maximizes time in target areas at high ecliptic latitudes searching for new planets; observations targeting regions with known planets; and observations of targets of opportunity that have high priority.

Maximum photometric accuracy and time on target could best be achieved by scheduling the observation of targets that are not time critical when they are ~ 74 ± 5 degrees from the sun.

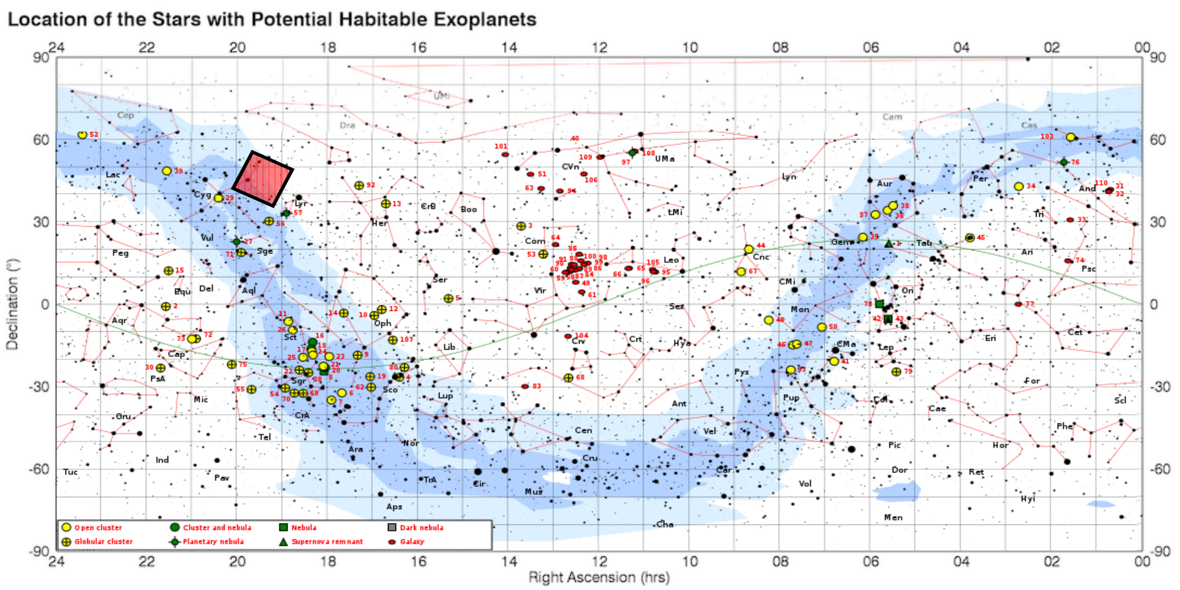

Figure 2. Star Chart showing stars with potential habitable planets and the the Kepler Star Field located at 55 degrees ecliptic latitude. The Kepler field will bi in the "Sweet Spot" twice each year (with the spot leading at trailing the Sun) for

Potential Targets

Depending on the photometric accuracy that can be obtained by observations in the "Sweet Spot," it may well be possible to observe known transiting planets in regions outside the Kepler Field, as well as to discover new candidate planets. Twice each year it would be possible to revisit the Kepler Star Field. Several new star fields could also be identified and each field could be observed for 30 to 35 days each year.

Stellar seismology observations should still be possible, albeit with less precision than before the second reaction wheel failure. All types of variable stars, cataclysmic variables, and Active Galactic Nuclei are potential targets for alternative Kepler investigations. Observations of solar system objects would also be possible, including asteroid light curves and, perhaps, photometry of comets and some Kuiper belt objects.

Summary

The pointing accuracy and photometric accuracy of the Kepler spacecraft can be maximized by aligning its Center of Mass with its Center of Pressure to minimize the disturbance torque due to solar radiation pressure, thereby minimizing the control authority required for precision pointing. My calculations indicate this can be achieved by tilting the spacecraft ~15 degrees toward the Sun. Thus there should be a "Sweet Spot" (SS) for precision pointing at ~74 degrees from the Sun. All objects at Ecliptic Latitudes less than ~80 degrees can be observed in this SS for 10 to 30 days each year, including the original Kepler Star Field.

A wide variety of objects are potential targets for an Alternative Kepler Science Investigations, including transiting planets, variable stars, cataclysmic variables, AGNs and solar system objects.